



# LHC Beam Instrumentation & Commissioning

## Tune Feedback Review

BNL - 4<sup>th</sup>-5<sup>th</sup> April 2005

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# Commissioning The LHC

(M. Lamont AB/OP – LHC Workshop, Jan 2005)

## Commissioning the LHC with beam Stage One

- Establish colliding beams as quickly as possible
- Safely
- Without compromising further progress

Take two moderate intensity multi-bunch beams to high energy and collide them.



# Beam Types for Commissioning

- Pilot Beam:
  - Single bunch, 5 to  $10 \times 10^9$  protons
  - Possibly reduced emittance
- Intermediate single:
  - 3 to  $4 \times 10^{10}$  ppb
- 4 bunches etc. pushing towards...
- 43 bunches
  - 3 to  $4 \times 10^{10}$  ppb



## First turn

- Commission injection region
- Instrumentation
- Threading

PILOT

RING 1  
RING2



## Establish circulating beam

- Circulating low intensity beam

PILOT

RING 1  
RING2



## 450 GeV Initial

- Polarities and aperture checked.
- Basic optics checks performed.
- First pass commissioning of BI performed.
- Phase 1 of machine protection system commissioning performed. .
- Beam Dump commissioned with beam

SINGLE  
INTERMEDIATE

RING 1  
RING2



## 450 GeV Detailed

- Well-adjusted beam parameters, detailed optics checks
- Fully functioning beam instrumentation.
- Machine protection as required for ramp
- RF - beam control loops operational and adjusted

SINGLE  
INTERMEDIATE  
++

RING 1  
RING2



## Two beam operation

- 2 beams, well-adjusted beam parameters,
- beam instrumentation, cross talk etc.



## Switch to nominal

- 2 beams, well-adjusted beam parameters,
- beam instrumentation, cross talk etc.



## Snapback

- Single beam, good transmission through snapback
- Requisite measurements (orbit, tune, chromaticity)

PILOT++

RING 1  
RING2



## Ramp Single Beam

- Single beam, good transmission to top energy
- **Commission beam dump in ramp**
- Stops in ramp - measurements
- RF

PILOT++

RING 1  
RING2



## Two beams to top energy

- Two beams, good transmission to top energy
- Measurements

43 x 43

COLLIDE



## Squeeze

- Single beam - step through squeeze
- Parameter control, measurements

SINGLE  
INTERMEDIATE

RING 1  
RING2



# At each phase:

- Equipment commissioning with beam
- Instrumentation commissioning
- Checks with beam
  - BPM Polarity, corrector polarity, BPM response
- Machine protection
- Beam measurements
  - beam parameter adjustment, energy, linear optics checks, aperture etc. etc.



# Instrumentation – the essentials

(H. Schmickler AB/BDI – LHC Workshop, Jan 2005)

- **First turn i.e. immediately**
  - Screens, BPMs, fast BCT, BLMs
- **Circulating beams at 450 GeV**
  - BPMs, DC BCT & lifetime, BLMs
  - Tune & chromaticity
  - Emittance: wire scanners..
- **Snapback and Ramp**
  - Continuous Tune & Chromaticity
  - Orbit
  - BLMs to beam interlock controller etc.



# Beam Commissioning: Tune measurement

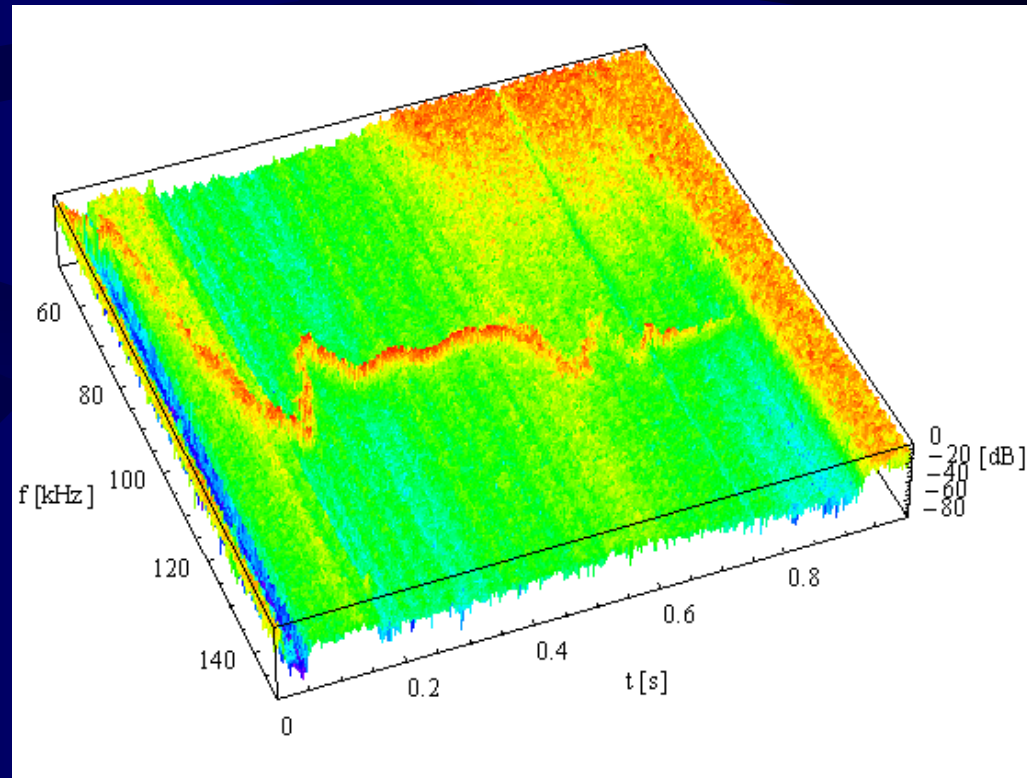
## Day 1 - Time resolved measurements:

- sequence of kick stimuli (2Hz) with FFT based tune measurements
- provides more information than a PLL trace and will be available from the start.

## PLL tune tracking:

- The PLL will need at least a few weeks to be set up
- US-LARP collaboration ongoing.
- Difficult to say when first system will be operational.

Compatibility with transverse damping so far unclear.







# Beam Commissioning: Chromaticity

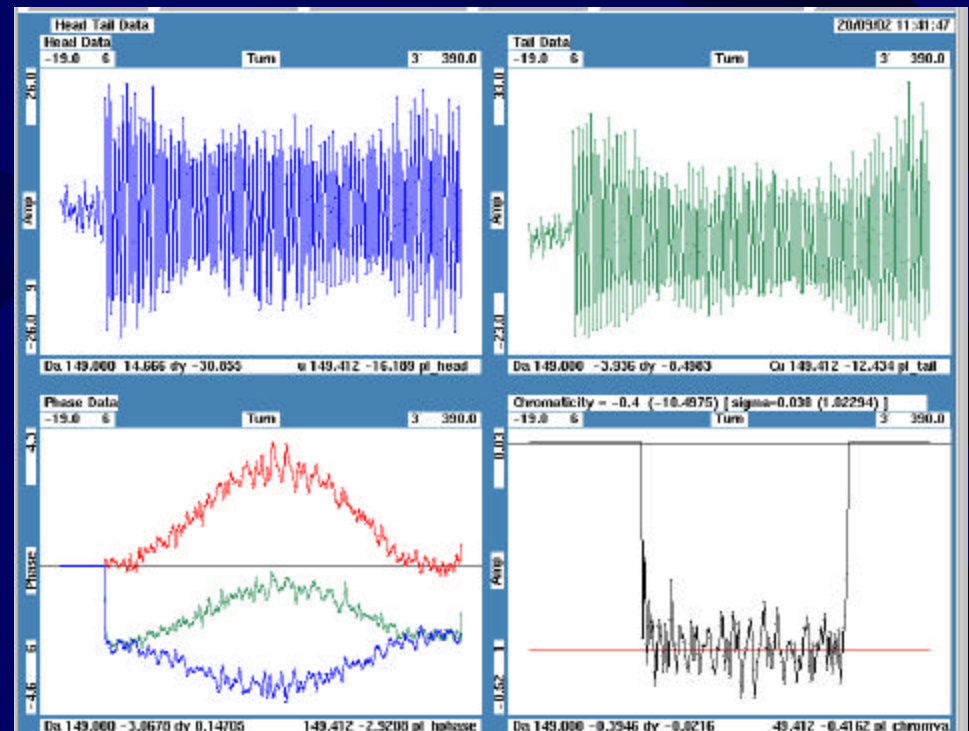
## Day 1 - Head-Tail analysis

- sequence of kick stimuli (2Hz) with head-tail based Q' measurements
- requires beam synchronous timing
- betatron oscillation has to last at least 50% of a synchrotron period.

Alternative: difference in tune for two discrete settings of beam momentum

## PLL tune tracking:

- Chromaticity tracking via periodic momentum modulation will be available as soon as the PLL works.

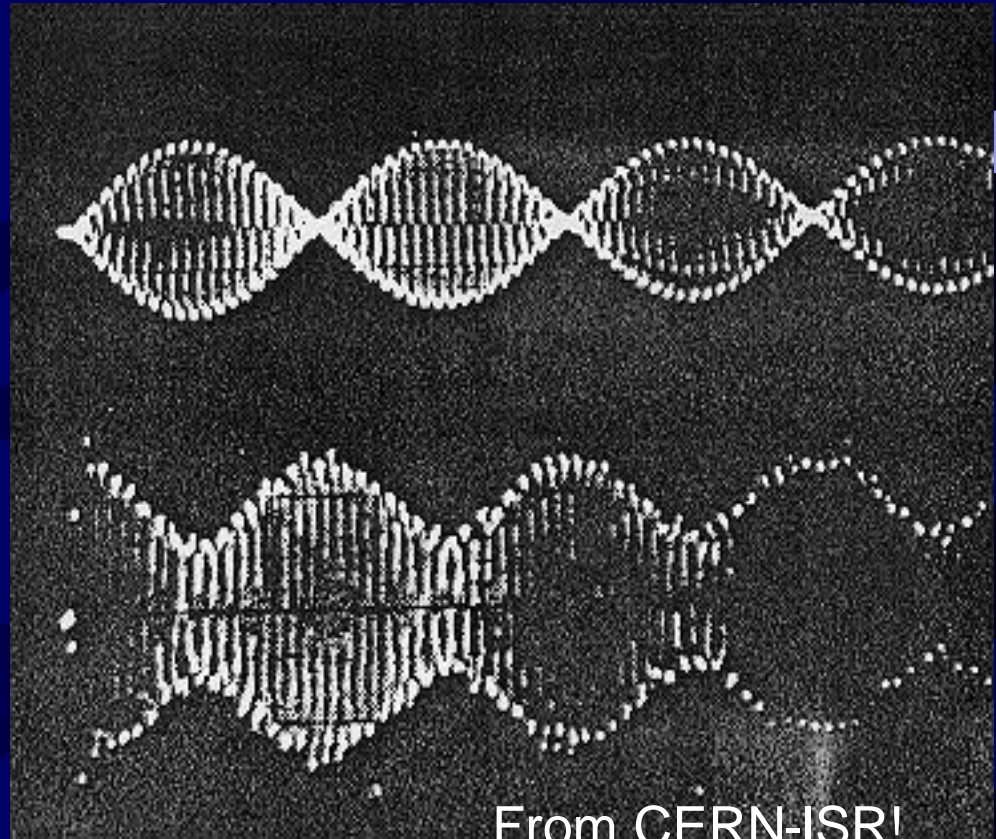
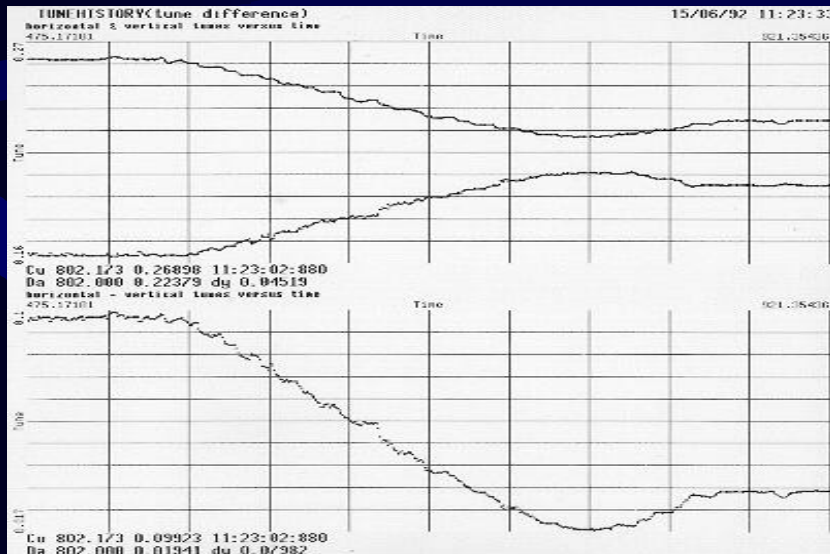




# Beam Commissioning: Chromaticity

## Day 1

- Again kick as beam stimulus.
- Coupling (in particular if large) from cross talk to other plane



From CERN-ISR!

## Day N

- with PLL available: closest tune approach measurement



# Transverse Diagnostics Commissioning

- Clear two step approach:
  - 1) Day 1 with kicked beams and classical motion analysis
  - 2) Day N with PLL and more powerful time resolved methods
- This puts a high pressure on getting dedicated machine time in order to commission the PLL early.
- As long as emittance growth is not the major concern, the problems will be:
  - automation of parameter settings depending on beam conditions
    - filters, gain switches, timings etc
    - phase scans in order to determine the correct PLL lock conditions
- For operational beams the additional problems will be:
  - lowering the excitation level to an insignificant level
  - coping with coupling
  - achieving compatibility with resistive transverse damping



# Tune Feedback Commissioning

## Three step approach:

### 1) Day N get PLL working as a tune tracker – this involves:

- Setting-up & debugging the acquisition system with beam
- Automation of parameter settings
- Phase scans to determine correct PLL lock conditions
- Investigating the influence of 60Hz components
- Investigating the effects of coupling
  - Can we stay locked in the presence of coupling?
  - Can we measure the coupling in order to stay locked?
- commissioning chromaticity measurement using the PLL

### 2) Day N+ close the loop and feedback on the tunes

- Test of the complete feedback chain
- Determine the best loop parameters
- Requires robust PLL
  - may require coupling to be understood & corrected

### 3) Day N++ close the loop and feedback on chromaticity & coupling

- Test of the complete feedback chain
- Determine the best loop parameters



# Tune Feedback Commissioning Timescales

## 2005/2006

- Test of complete LHC prototype acquisition chain at RHIC

## 2006

- Implement prototype LHC PLL system in the SPS
- Possible test of tune feedback in the SPS

## 2007

- Test of tune feedback in the SPS
- Installation & hardware commissioning of the LHC system
- Commission the LHC PLL system with beam
- Commission chromaticity & coupling measurement using the PLL

## 2008

- Commission tune feedback in the LHC
- Commission chromaticity & coupling feedback in the LHC